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5-THIO-D-RIBOPYRANOSE

PART IV[1]. SULPHOXIDES AND SULPHONES*

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ABSTRACT

Oxidation of methyl 5-thio-β-D-ribopyranoside (**1b**) with hydrogen peroxide–acetic acid gave first the diastereoisomeric methyl 5-thio-β-D-ribopyranoside (*R*)- and (*S*)-*S*-oxides (**2b** and **3b**), which were further converted into methyl 5-thio-β-D-ribopyranoside *S*,*S*-dioxide (**4b**) on prolonged reaction. The triacetates **2'b** and **3'b** of the sulphoxides **2b** and **3b** can also be obtained from methyl 2,3,4-tri-*O*-acetyl-5-thio-β-D-ribopyranoside (**1'b**) by reaction with sodium metaperiodate. Similar oxidations have been applied to methyl 5-thio-α-D-ribopyranoside (**1a**) and the related triacetate (**1'a**), as well as to 1,2,3,4-tetra-*O*-acetyl-5-thio-β-D-ribopyranose (**5**). Sulphoxide configurations were assigned from considerations of ^{1}H-n.m.r. data. The sulphoxides **2b** and **3b** were stable to base, but were converted by aqueous or methanolic acid into bis(5-deoxy-D-ribofuranose) 5,5'-disulphide and glycosides thereof, respectively. By contrast, the sulphone **4b** was stable to acid, but underwent considerable degradation on treatment with base.

INTRODUCTION

Sugars and their derivatives containing sulphur in place of the ring oxygen atom can give rise to a new type of carbohydrate by oxidation of the sulphur to the sulphoxide or sulphone levels. Whistler and his colleagues have already explored[2] this possibility in the 5-thio-D-xylopyranose series and obtained a number of sulphoxides and sulphones, though they were able only to make tentative assignments of the sulphoxide configurations. We now report on derivatives of 5-thio-D-ribopyranose.

*Dedicated to the memory of Dr. Hewitt G. Fletcher, Jr.

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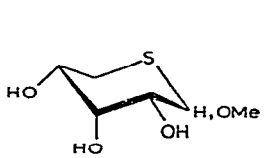
DISCUSSION

Syntheses. — Examination of the reaction of methyl 5-thio-β-D-ribopyranoside (**1b**) with hydrogen peroxide in acetic acid showed that the oxidation proceeded to the sulphoxide stage readily at 0°, but further oxidation to the sulphone **4b** required higher temperatures. Two sulphoxides **2b** (50%) and **3b** (28%) were obtained which were separated by chromatography on a basic ion-exchange resin (see later for configurational assignments); both could be further oxidised by hot hydrogen peroxide–acetic acid to the sulphone **4b**. The sulphoxides **2b** and **3b**, and the sulphone **4b**, all gave crystalline triacetates, **2'b**, **3'b**, and **4'b**, respectively. In simple systems, the ratio of sulphoxides formed by periodate oxidation is different to that obtained by peroxide oxidation[3]. This was not so for methyl 2,3,4-tri-*O*-acetyl-5-thio-β-D-ribopyranoside (**1'b**) which, with sodium metaperiodate in aqueous methanol, gave the sulphoxides **2'b** (46%) and **3'b** (26%), separated by fractional crystallisation, in much the same ratio as obtained above in the peroxide reaction on the unacetylated glycoside **1b**. Interestingly, the oxidation of the triacetate **1'b** by peroxide in acetic acid was much less-selective and led to mixtures of the sulphone **4'b**, the sulphoxides **2'b** and **3'b**, as well as the starting material **1'b**.



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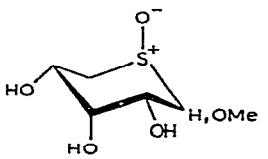

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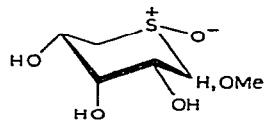

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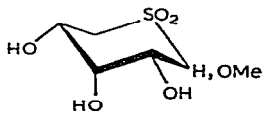

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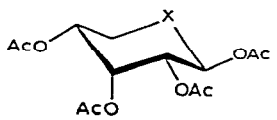
a series : α – anomers b series : β–anomers

(The related 2,3,4-triacetates are indicated by a prime notation, *e.g.*, **1'a**).

Periodate oxidation of methyl 2,3,4-tri-*O*-acetyl-5-thio-α-D-ribopyranoside (**1'a**) gave preponderantly a crystalline sulphoxide **2'a**. Paper-chromatographic examination of the mother liquors, after deacetylation, showed the presence of two sulphoxides. These were separated by chromatography on a basic ion-exchange resin, but neither could be crystallised. Acetylation of each gave an additional amount of **2'a** (total: 83%) and a small amount (5%) of the diastereoisomeric sulphoxide (**3'a**). Oxidation of methyl 5-thio-α-D-ribopyranoside with cold hydrogen peroxide in acetic acid gave the sulphoxides **2a** and **3a**, with **2a** again preponderating. More vigorous

oxidation conditions gave a compound tentatively identified as the sulphone **4a**, but neither it nor the related triacetate **4'a** could be obtained crystalline.

Oxidation of 1,2,3,4-tetra-*O*-acetyl-5-thio-β-D-ribopyranose (**5**) to the related sulphoxides **6** and **7** by the periodate route proved impracticable, as the starting material co-crystallised with the sodium metaperiodate, thus precluding complete reaction. Fortunately, in this case, selective oxidation to the sulphoxides **6** (58%) and **7** (23%), separated by fractional crystallisation, could be achieved by a brief treatment of **5** with warm hydrogen peroxide in acetic acid. As before, more-prolonged oxidation converted these sulphoxides or the original starting material **5** into the sulphone **8**.



5 X = S **6** X = $\overset{+}{S}—\bar{O}$ (ax)

8 X = SO_2 **7** X = $\overset{+}{S}—\bar{O}$ (eq)

Sulphoxide configurations. — The minor product **3a** formed in the α-series can reasonably be assigned the all *cis* (*S*)-configuration on steric grounds because oxidation might be expected to occur more readily on the less-hindered side of the ring. However, such considerations cannot readily be applied in the β-series.

Fortunately, in recent years, n.m.r. studies on thiane oxides and related compounds have revealed two effects which allow the sulphoxide configuration in these compounds to be assigned[4]. The first is the *syn*-axial effect, where the signals for axial β-hydrogens are found at lower field when the sulphoxide group is axial than when it is equatorial; clearly, the ring conformation and the solvent must remain the same for this criterion to be applied. The second is that the geminal coupling constant in an α-methylene group is smaller when the sulphoxide configuration is equatorial than when it is axial. The acetates **1'–4'** gave better-resolved spectra than the parent triols, and the ^{1}H-nm.r. parameters of the ring hydrogens of these compounds and the tetra-acetates **5–8** are given in Table I. All spectra were determined for solutions in deuterochloroform; some were also determined for solutions in benzene, when this resulted in a better-resolved spectrum.

In the series of compounds **1'b–4'b** arising from methyl 5-thio-β-D-ribopyranoside (**1b**), the high values of $J_{1,2}$ and $J_{4,5a}$ clearly indicate these compounds to be in the $^4C_1$ conformation, though in the case of **1'b** the slightly lower values suggest a contribution from the $^1C_4$ form[1]. Although the signals of the axial H-2 and H-4 of **2'b** are in the multiplet at τ 4.15–4.35, they are clearly at lower field than the signals for the corresponding hydrogens of **3'b** (τ 4.95 and 4.97, respectively) and indicate the sulphoxide configuration in **2'b** to be axial and that of **3'b** to be equatorial. The lower value (11.9 Hz), albeit in benzene, of the geminal coupling constant of H-5e and H-5a in **3'b**, compared with that of **2'b** (14.0 Hz), supports this structural assignment. It is noteworthy that this last coupling constant is comparable with those of the sulphide **1'b** (13.8 Hz) and the sulphone **4'b** (14 Hz).

In the α-series, **1'a** and **3'a** clearly have the $^4C_1$ conformation ($J_{4,5a}$ 11.8 and

TABLE I

FIRST-ORDER CHEMICAL SHIFTS[a] AND COUPLING CONSTANTS[b] OF RING PROTONS OF ACETATES 1′–8 (100 MHz)

Compound	*Solvent*	*H-1*	*H-2*	*H-3*	*H-4*	*H-5e*	*H-5a*	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5e}$	$J_{4,5a}$	$J_{5e,5a}$	$J_{3,5e}$
1′a	$CDCl_3$	5.48	4.80	4.41	4.89	7.66	6.90	3.9	2.6	3.0	4.2	11.8	12.8	1.0
	C_6H_6	5.66	4.78	4.19	4.88	7.90	6.95	3.8						
2′a	$CDCl_3$	5.45	←	4.35–4.45	→	←	6.85 →	3.8						
3′a	$CDCl_3$	5.10	5.10	4.60	5.10	6.87	6.29				~4	12.2	10.9	
1′b	$CDCl_3$	5.36	4.78	4.58	4.81	←	7.17 →	7.7		2.8	4.2			
	C_6H_6	5.44	4.53	4.38	4.85	7.57	7.37	7.6	2.9	2.9	4.3	7.6	13.8	<0.5
2′b	$CDCl_3$	5.72	←	4.15–4.35	→	6.62	7.15	10.0			3.2	11.4	14.0	
3′b	$CDCl_3$	5.49	4.95	4.49	4.97	←	6.6 →	11.0	2.7	2.7	5.8	11.2		
	C_6H_6	5.44	4.78	4.40	5.13	6.92	6.70	11.0	2.7	2.4	4.2	12.0	11.9	1.2
4′b	$CDCl_3$	5.45	4.77	4.35	4.70	6.55	6.45	10.3	2.6	2.3	6.0	10.3	14.0	
5	$CDCl_3$	3.95	4.77	4.48	4.81	7.27	6.90	8.8	2.8		4.2	9.8	13.2	
	C_6H_6	3.65	4.54	4.27	4.93	7.67	7.17	8.8	2.8	2.8	4.2	10.1	13.2	1.2
6	$CDCl_3$	←	4.15–4.30		→	6.62	6.99				4.2		13.9	
7	$CDCl_3$	3.77	4.93	4.43	4.93	←	6.5 →	11.1	2.8					
	C_6H_6		4.87	4.27	5.22	7.00	6.67	11.1	2.7	2.8	4.0	12.3	12.0	1.3
8	$CDCl_3$	3.77	4.61	4.24	4.61	←	6.4 →	11.0	2.5					

[a] τ values. [b] In Hz.

12.2 Hz, respectively), but the lack of resolution of the spectrum of **2'a** does not permit an assignment of its conformation to be made. However, there is no obvious reason why the conformation of **2'a** should be different from those of **1'a** and **3'a** and, making this assumption, chemical-shift considerations, as for the β-series, imply that **2'a** has the axial sulphoxide group. Unfortunately, a comparison of geminal coupling constants is not possible in this case since the H-5e and H-5a signals of **2'a** could not be resolved, but the assignment is supported by a comparison of the geminal coupling constant of **3'a** (10.9 Hz) with that of the sulphide **1'a** (12.8 Hz). Finally, the assignment is in agreement with that made earlier on steric grounds.

Again, with the tetra-acetates **5–8**, the assumption must be made that **6** is in the $^4C_1$ conformation, as **5**, **7**, and **8** clearly are from the values of $J_{1,2}$ and $J_{4,5a}$. Both coupling-constant and chemical-shift criteria then clearly indicate **6** to have the axial sulphoxide group and **7** to be the equatorial epimer.

In all the reactions leading to sulphoxides, there appears to be a preference for axial attack with both α- and β-anomers, regardless of whether periodate or hydrogen peroxide–acetic acid is employed; such attack is the usual preference in periodate oxidations[3].

The optical rotations of the sulphoxides **2'**, **3'**, **6**, and **7**, the sulphones **4'b** and **8**, and the parent sulphides **1'** and **5** are shown in Table II. For the β-compounds, where a full comparison is possible, it can be seen that whereas the optical rotations of related sulphides and sulphones are similar, the additional asymmetry in the sulphoxides introduces negative and positive contributions in the (*R*)-oxides and

TABLE II

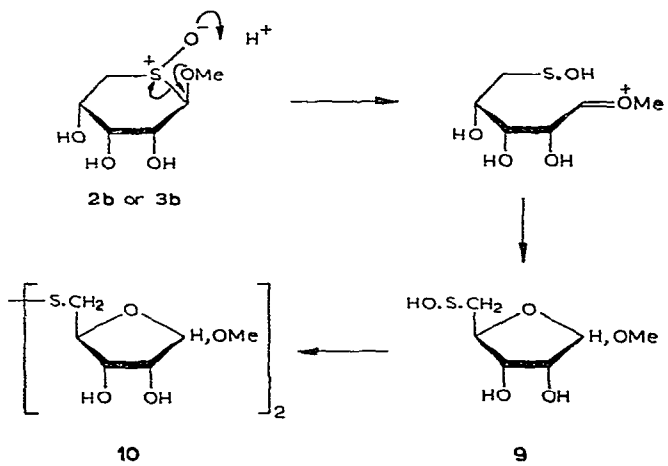
OPTICAL ROTATIONS OF SULPHOXIDES, SULPHONES, AND PARENT SULPHIDES

Parent compound	*Unoxidised*		(R)-S-*oxide*		(S)-S-*oxide*		S,S-*dioxide*	
1,2,3,4-Tetra-*O*-acetyl-5-thio-β-D-ribopyranoside	**5**	−61°[a]	**6**	−125°[b]	**7**	+21°[b]	**8**	−69°[b]
Methyl 2,3,4-tri-*O*-acetyl-5-thio-β-D-ribopyranoside	**1'b**	−78°[a]	**2'b**	−147°[b]	**3'b**	+50.5°[b]	**4'b**	−63.5°[b]
Methyl 2,3,4-tri-*O*-acetyl-5-thio-β-D-xylopyranoside		−70.6°[c]		−133°[c]		+27.2°[c]		−69°[c]
Methyl 2,3,4-tri-*O*-acetyl-5-thio-α-D-ribopyranoside	**1'a**	+227°[a]	**2'a**	+127°[b]	**3'a**	+146°[b]		—
Methyl 2,3,4-tri-*O*-acetyl-5-thio-α-D-xylopyranoside		+228°[c]		+134°[c]		—		+80°[c]

[a]In methanol. [b]In dichloromethane. [c]In chloroform.

(*S*)-oxides, respectively. Table II also shows the optical rotations of some analogous *xylo* compounds[2], and the close correlation between these rotations and those of the *ribo* compounds suggests that the original, tentative assignments of configuration were correct. Although n.m.r. evidence is not available, the *xylo* compounds undoubtedly also exist in the $^4C_1$ conformation.

Reaction with acids and bases. — The sulphone **4b** was unaffected by aqueous or methanolic hydrogen chloride. The corresponding sulphoxides **2b** and **3b**, by contrast, were transformed by methanolic hydrogen chloride into three products, chromatographically indistinguishable from the $\alpha\alpha$, $\alpha\beta$, and $\beta\beta$ forms of bis(methyl 5-deoxy-D-ribofuranoside) 5,5′-disulphide[5], and the $\beta\beta$ form was isolated as the bis-isopropylidene derivative. These products presumably arise *via* the sulphenic acids **9**, formed by protonation of the sulphoxide group in **2b** or **3b** (see Scheme 1), which then disproportionate[6] into the disulphides **10** and sulphonic and sulphinic acids. Ktuhn and co-workers have reported[7] a similar reaction of an *S*-oxide of ethyl 1-hio-α-D-glucofuranoside which afforded methyl D-glucosides and diethyl disulphide. The sulphoxides **2b** and **3b** were unaffected in the cold, but with hot, dilute hydrochloric acid they gave a reducing sugar chromatographically identified as bis(5-deoxy-D-ribofuranose) 5,5′-disulphide and which was assumed to have arisen *via* the glycosides **10**. Under similar aqueous conditions, no reaction was observed by Whistler and Rowell[8] on the corresponding *xylo* sulphoxides.



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Scheme 1.

The sulphoxides **2** and **3** and the sulphone **4b** were sufficiently stable to alkali to enable them to be chromatographed on a basic ion-exchange resin. However, more-prolonged treatment of the sulphone **4b** with dilute sodium hydroxide resulted in its degradation into a complex mixture of products; as a β-hydroxy sulphone, **4b** might be expected to undergo a retro-aldol reaction, the product of which could then undergo further decomposition.

Attempts to deacetylate the free-sugar sulphoxides **6** and **7**, or the sulphone **8**, with either sodium methoxide in methanol or with ammonia also led to complex product mixtures; a similar result has been observed[8] with the *xylo* analogue of the sulphone **8**.

EXPERIMENTAL

For general procedures, see Part I[5]. N.m.r. spectra were obtained at 100 MHz with a JEOL JNM-4H-100 spectrometer, with tetramethylsilane as an internal reference. R_F values refer to paper chromatography on Whatman No. 1 paper in butan-1-ol–water (86:14, v/v).

*Methyl 5-thio-β-*D*-ribopyranoside* (R)- *and* (S)-S-*oxides* (**2b** *and* **3b**). — Methyl 5-thio-β-D-ribopyranoside[5] (**1b**) (1.2 g) in glacial acetic acid (120 ml) containing hydrogen peroxide (30%, 12 ml) was kept at 0° during 6 h. Solvents were removed by evaporation (bath temperature: 40°), and the residue was dissolved in water and chromatographed on a column (34 × 4 cm) of Dowex-1 (HO^-) resin, by elution with water (250-ml fractions). Fractions 6–8 contained the (*R*)-sulphoxide **2b** (0.65 g) which, after recrystallisation from methanol, had m.p. 202–205°, $[\alpha]_D$ −234° (*c* 0.5, methanol), R_F 0.16 (Found: C, 36.7; H, 6.3; S, 16.1. $C_6H_{12}O_5S$ calc.: C, 36.7; H, 6.2; S, 16.3%). Fractions 16–22 contained the (*S*)-sulphoxide **3b** (0.37 g) which, after recrystallisation from ethanol, had m.p. 179–183°, $[\alpha]_D$ +106° (*c* 0.7, methanol), R_F 0.22 (Found: C, 36.8; H, 6.3; S, 16.8%).

*Methyl 5-thio-β-*D*-ribopyranoside* S,S-*dioxide* (**4b**). — (*a*) *From methyl 5-thio-β-*D*-ribopyranoside* (**1b**). A solution of the glycoside **1b** (0.18 g) in glacial acetic acid (20 ml) containing hydrogen peroxide (30%, 2 ml) was kept at 70° for 3 h. Removal of the solvents under reduced pressure and crystallisation of the residue from ethanol gave the sulphone **4b** (0.15 g), m.p. 176–178°, $[\alpha]_D$ −74° (*c* 1.0, methanol), R_F 0.36 (Found: C, 33.9; H, 5.7; S, 15.0. $C_6H_{12}O_6S$ calc.: C, 34.0; H, 5.7; S, 15.1%).

(*b*) *From methyl 5-thio-β-*D*-ribopyranoside* (R)- *and* (S)-S-*oxides* (**2b**) *and* (**3b**). Treatment of each sulphoxide (20 mg) as in (*a*) gave, in each case, the sulphone **4b** (13 mg), m.p. and mixture m.p. 176–179°.

*Methyl 2,3,4-tri-*O*-acetyl-5-thio-β-*D*-ribopyranoside* (R)- *and* (S)-S-*oxides* (**2'b**) *and* (**3'b**). — (*a*) *From the oxides* **2b** *and* **3b**. Each oxide (98 mg) was stirred with pyridine (1 ml) and acetic anhydride (0.5 ml) until dissolution was achieved, and the solutions were then left overnight at room temperature before work-up in the usual manner.

The triacetate **2'b** (150 mg) readily crystallised from ether–dichloromethane and then had m.p. 183–185°, $[\alpha]_D$ −147° (*c* 0.5, dichloromethane) (Found: C, 44.4; H, 5.5; S, 9.6. $C_{12}H_{18}O_8S$ calc.: C, 44.7; H, 5.6; S, 9.9%).

The triacetate **3'b** (144 mg), crystallised from isopropyl ether, had m.p. 98–100°, $[\alpha]_D$ +50.5° (*c* 0.8, dichloromethane) (Found: C, 44.3; H, 6.0; S, 9.8%).

(*b*) *From methyl 2,3,4-tri-*O*-acetyl-5-thio-β-*D*-ribopyranoside* (**1'b**). Sodium metaperiodate (0.1 g) in water (7.5 ml) was added to the triacetate **1'b**[1] (85 mg) in

methanol (5 ml), and the mixture was kept at room temperature for two days. The methanol was removed by evaporation, and the aqueous mixture was extracted with dichloromethane to give the product mixture (80 mg). Crystallisation from ether gave the (*R*)-sulphoxide triacetate **2'b** (41 mg), m.p. and mixture m.p. 183–185°; the mother liquors yielded the (*S*)-sulphoxide triacetate **3'b** (23 mg), m.p. 93–95° and mixture m.p. 96–98° (from isopropyl ether).

*Methyl 2,3,4-tri-*O*-acetyl-5-thio-β-*D*-ribopyranoside* S,S*-dioxide* (**4'b**). — Acetylation of the triol **4b** (106 mg) with acetic anhydride (0.5 ml) in pyridine (1.0 ml) overnight at room temperature, followed by the usual work-up procedure, gave the triacetate **4b** (150 mg), m.p. 118–120° (from ether), $[\alpha]_D$ −63.5° (*c* 0.6, dichloromethane) (Found: C, 42.6; H, 5.7; S, 9.5. $C_{12}H_{18}O_9S$ calc: C, 42.6; H, 5.35; S, 9.5%).

*Methyl 2,3,4-tri-*O*-acetyl-5-thio-α-*D*-ribopyranoside* (R)- *and* (S)-S*-oxides* (**2'a**) *and* (**3'a**). — (*a*) *From methyl 2,3,4-tri-*O*-acetyl-5-thio-α-*D*-ribopyranoside* (**1'a**). A solution of sodium metaperiodate (0.75 g) in water (55 ml) was added to the glycoside **1'a**[5] (0.64 g) in methanol (35 ml). After 41 h at room temperature, the methanol was evaporated off and the aqueous solution was extracted with dichloromethane. Crystallisation of the extract from ether gave the (*R*)-sulphoxide **2'a** (0.49 g), m.p. 143–145°, $[\alpha]_D$ +127° (*c* 0.5, dichloromethane) (Found: C, 44.6; H, 5.5; S, 9.75%; mol. wt., 322.0728. $C_{12}H_{18}O_8S$ calc.: C, 44.7; H, 5.6; S, 9.9%; mol. wt., 322.0722). The mother liquors were evaporated to dryness, and the residue was deacetylated for 1 h in methanolic sodium methoxide (0.1M, 4 ml) before chromatography on a column (18 × 1.2 cm) of Dowex-1 (HO^-) with water (9-ml fractions). Fractions 6–8 contained material (25 mg) that was chromatographically indistinguishable from the glycoside **1a**, fractions 16–21 contained the (*R*)-sulphoxide **2a** (34 mg), R_F 0.18, and fractions 23–30 contained the (*S*)-sulphoxide **3a** (18 mg), R_F 0.13. Neither **2a** nor **3a** could be obtained crystalline, and they were re-acetylated as described earlier for **2b** and **3b**. The (*R*)-sulphoxide **2a** gave the triacetate **2'a**, m.p. 143–145°, whereas the (*S*)-sulphoxide **3a** gave a syrupy triacetate **3'a**, $[\alpha]_D$ +146° (*c* 0.8, dichloromethane) (Found: mol. wt., 322.0724).

(*b*) *From methyl 5-thio-α-*D*-ribopyranoside* (**1a**). Oxidation of the glycoside **1a**[5] (50 mg), as described for the β-anomer **1b**, gave a syrupy product (52 mg), paper chromatography of which showed it to be mainly composed of the (*R*)-sulphoxide **2a** together with a small proportion of the (*S*)-sulphoxide **3a**. Acetylation of the product gave the triacetate **2'a** (32 mg), m.p. and mixture m.p. 142–144°.

*Oxidation of methyl 5-thio-α-*D*-ribopyranoside* (**1a**) *with hot hydrogen peroxide–acetic acid.* — The glycoside **1a** (50 mg) was kept in glacial acetic acid (5 ml) containing hydrogen peroxide (30%) (0.5 ml) for 2 h at 75°. Evaporation yielded a residue (70 mg) which could not be crystallised, though paper chromatography indicated only a single component (R_F 0.32). Acetylation of the product failed to produce a crystalline derivative.

*1,2,3,4-Tetra-*O*-acetyl-5-thio-β-*D*-ribopyranose* (R)- *and* (S)-S*-oxides* (**6**) *and* (**7**). — The tetra-acetate **5**[5] (0.20 g) was kept at 70° in acetic acid (8 ml) containing hydrogen peroxide (30%, 0.8 ml) for 20 min. Solvents were evaporated off and last

traces were removed by co-evaporation with ethanol–toluene. Crystallisation of the residue from methanol gave the (*R*)-sulphoxide **6** (142 mg), m.p. 213–217°, $[\alpha]_D$ −125° (*c* 0.6, dichloromethane) (Found: C, 45.1; H, 5.4; S, 9.1%; mol. wt., 350.0682. $C_{13}H_{18}O_9S$ calc.: C, 44.6; H, 5.2; S, 9.1%; mol. wt., 350.0672).

From the mother liquors, the (*S*)-sulphoxide **7** (49 mg) was obtained; m.p. 164–167° (from ether), $[\alpha]_D$ +21° (*c* 0.6, dichloromethane) (Found: C, 45.2; H, 5.5; S, 9.0%; mol. wt., 350.0679.

1,2,3,4-Tetra-O-*acetyl-5-thio-β*-D-*ribopyranose* S,S-*dioxide* (**8**). — (*a*) *From the tetra-acetate* **5**. The tetra-acetate **5** (200 mg) was treated as in the previous experiment, but for the longer period of 5 h. The sulphone **8** (210 mg) was crystallised from methanol and had m.p. 159–161°, $[\alpha]_D$ −69° (*c* 0.9, dichloromethane) (Found: C, 42.7; H, 5.0; S, 8.7. $C_{13}H_{18}O_{10}S$ calc.: C, 42.6; H, 4.95; S, 8.7%).

(*b*) *From the sulphoxides* **5** *and* **6**. Each sulphoxide (40 mg) was kept in acetic acid (2 ml) containing hydrogen peroxide (30%, 0.2 ml) at 70° for 5 h. Evaporation of solvents and crystallisation from methanol gave, in each case, the sulphone **8** (20 mg), m.p. and mixture m.p. 159–161°.

Reactions of sulphoxides **2b** *and* **3b**. — (*a*) *With 0.2*M *hydrochloric acid.* Samples of each sulphoxide (2 mg) were kept in 0.2M hydrochloric acid for 72 h at room temperature, and paper chromatography then showed them to be unchanged. Heating the solution to 80° for 3 h resulted in the production, in each case, of a reducing sugar disulphide (R_F 0.16) that was chromatographically indistinguishable from bis(5-deoxy-D-ribofuranose) 5,5′-disulphide[5].

(*b*) *With methanolic hydrogen chloride.* Solutions of each sulphoxide (3 mg) in methanolic hydrogen chloride (4%, 0.5 ml) were kept for 48 h at room temperature, and paper chromatography then showed the complete conversion of the sulphoxides into three non-reducing disulphides (R_F 0.60, 0.51, and 0.45) that were chromatographically indistinguishable from the *ββ*, *αβ*, and *αα* forms of bis(methyl 5-deoxy-D-ribofuranoside) 5,5′-disulphide[5].

On a preparative scale, treatment of **2b** (33 mg) as described above was followed by removal of solvents and addition of acidified acetone. After 12 h, the acid was neutralised and the solution evaporated to dryness. Crystallisation of the residue from methanol yielded bis(methyl 5-deoxy-2,3-*O*-isopropylidene-*β*-D-ribofuranoside) 5,5′-disulphide, m.p. and mixture m.p. 76–78°[5].

(*c*) *With 0.2*M *sodium hydroxide.* Paper chromatography indicated little change after the sulphoxides **2b** and **3b** (5 mg) had been kept in 0.2M sodium hydroxide for 36 h; the major components were still the sulphoxides. A similar result was obtained with sodium methoxide in methanol.

Reactions of methyl 5-thio-β-D-*ribopyranoside* S,S-*dioxide* (**4b**). — (*a*) *With 0.2*M *hydrochloric acid.* Paper chromatography showed the sulphone **4b** to be unchanged after being kept in 0.2M hydrochloric acid at 80° for 3 h.

(*b*) *With methanolic hydrogen chloride.* The sulphone **4b** was also unchanged after 24 h at room temperature in methanolic hydrogen chloride (4%).

(*c*) *With 0.5*M *sodium hydroxide.* Treatment of the sulphone **4b** (5 mg) with

0.5M sodium hydroxide (0.5 ml) for 24 h at room temperature resulted in its complete conversion into a complex mixture of products.

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